APPENDIX E
FCT DOCUMENT COVER SHEET [1]

Name/Title of Deliverable/Milestone/Revision No.	Nuclear Fuel Cycle Options Catalog: FY15 Improvements and Additions
Work Package Title and Number	Fuel Cycle Catalog M3FT-15SN1205051
Work Package WBS Number	1.02.12.05
Responsible Work Package Manager	Laura Price Laura LPrice (Name/Signature)
Date Submitted	

Quality Rigor Level for Deliverable/Milestone[2]	☒ QRL-3	☐ QRL-2	☐ QRL-1 Nuclear Data	☐ Lab/Participant QA Program (no additional FCT QA requirements)

This deliverable was prepared in accordance with Sandia National Laboratories
(Participant/National Laboratory Name)

QA program which meets the requirements of

☒ DOE Order 414.1 ☐ NQA-1-2000 ☐ Other

This Deliverable was subjected to:

☒ Technical Review ☐ Peer Review

Technical Review (TR)
Review Documentation Provided

☐ Signed TR Report or,
☐ Signed TR Concurrence Sheet or,
☒ Signature of TR Reviewer(s) below

Peer Review (PR)
Review Documentation Provided

☐ Signed PR Report or,
☐ Signed PR Concurrence Sheet or,
☐ Signature of PR Reviewer(s) below

Name and Signature of Reviewers

Rob P Rechard

NOTE 1: *Appendix E should be filled out and submitted with the deliverable. Or, if the PICS:NE system permits, completely enter all applicable information in the PICS:NE Deliverable Form. The requirement is to ensure that all applicable information is entered either in the PICS:NE system or by using the FCT Document Cover Sheet.*

NOTE 2: *In some cases there may be a milestone where an item is being fabricated, maintenance is being performed on a facility, or a document is being issued through a formal document control process where it specifically calls out a formal review of the document. In these cases, documentation (e.g., inspection report, maintenance request, work planning package documentation or the documented review of the issued document through the document control process) of the completion of the activity, along with the Document Cover Sheet, is sufficient to demonstrate achieving the milestone. If QRL 1, 2, or 3 is not assigned, then the Lab / Participant QA Program (no additional FCT QA requirements) box must be checked, and the work is understood to be performed and any deliverable developed in conformance with the respective National Laboratory / Participant, DOE or NNSA-approved QA Program.*

Nuclear Fuel Cycle Options Catalog: FY15 Improvements and Additions

Fuel Cycle Research & Development

Prepared for
U.S. Department of Energy
Fuel Cycle Options Campaign
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SUMMARY

The United States Department of Energy, Office of Nuclear Energy, Fuel Cycle Technology Program sponsors nuclear fuel cycle research and development. As part of its Fuel Cycle Options campaign, the DOE has established the Nuclear Fuel Cycle Options Catalog. The catalog is intended for use by the Fuel Cycle Technologies Program in planning its research and development activities and disseminating information regarding nuclear energy to interested parties. The purpose of this report is to document the improvements and additions that have been made to the Nuclear Fuel Cycle Options Catalog in the 2015 fiscal year.

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FIGURES

ACRONYMS

DOE	U. S. Department of Energy
DUPIC	Direct Use of Pressurized Water Reactor spent fuel in CANDU (Canada Deuterium Uranium)
FCDP	Fuel Cycle Data Package
FY	fiscal year
R&D	research and development
SNL	Sandia National Laboratories
TRISO	tristructural-isotropic
TRU	transuranic

NUCLEAR FUEL CYCLE OPTIONS CATALOG: FY15 IMPROVEMENTS AND ADDITIONS

1. INTRODUCTION

The United States Department of Energy (DOE), Office of Nuclear Energy, Fuel Cycle Technology Program sponsors nuclear fuel cycle research and development. As part of its Fuel Cycle Options campaign, the DOE is developing systematic, transparent, and objective processes to screen and evaluate a wide variety of proposed nuclear fuel cycles. The Nuclear Fuel Cycle Options Catalog is intended for use by the Fuel Cycle Technologies Program in planning its research and development (R&D) activities. The catalog is designed to

- Communicate fuel cycle information, including results from evaluations of proposed fuel cycles and their enabling technologies, that is part of the basis for Fuel Cycle Technology R&D investment decisions.
- Serve as a controlled source of input to fuel cycle evaluations and to screening analyses, such as those that are used to focus R&D investment in targeted areas.
- Archive information on nuclear fuel cycles and technologies, including information contributed by academic and industry stakeholders.
- Indicate whether nuclear fuel cycle options proposed in the future have been considered previously.
- Accumulate key results from fuel cycle analyses and related studies to support Fuel Cycle Technology R&D program planning by national technical directors and federal managers

The Nuclear Fuel Cycle Options Catalog is web-based and available to the public; it has been on the public site since March 2014. It can be found at

https://connect.sandia.gov/sites/NuclearFuelCycleOptionCatalog/SitePages/a/homepage.aspx

It can also be found from the Sandia National Laboratories (SNL) Nuclear Energy website, as shown in Figure 1 below.

The purpose of this report is to document the improvements and additions that have been made to the catalog in the 2015 fiscal year (FY).

Figure 1. Link to Nuclear Fuel Cycle Options Catalog on SNL Nuclear Energy Website

2. IMPROVEMENTS AND ADDITIONS

Several improvements and additions were made to the catalog in FY15. Some of the improvements involved database visualizations (i.e., requests to the database to provide information), some involved the website itself, some involved completion of documentation for the catalog, and some involved data entry. These improvements and additions are discussed below.

2.1 Enhanced Search Facility

One of the improvements made to the catalog in FY15 was the enhancement of the database search facility. The search facility allows a user to select parameters that are used to filter the information that is then shown to that user. The enhancements represent an improvement to the previous search facility in that the parameter box from which the user chooses parameters is on the left hand side of the page, which is where most users are accustomed to seeing it. The previous reports had the parameters in a separate window on the right hand side of the page where it often obstructed report information and was difficult to find. In addition the user can select parameters to filter results by expanding the selections. Selected items are highlighted to remind the user of the technology selected.

An example of the enhanced search facility is shown in Figure 2. The white-framed box on the left hand side of this figure shows the parameters that the user can choose to filter the fuel cycle options that are displayed: Fuel Cycle Strategy (e.g., continuous recycle, limited recycle, no recycle), Number of Stages, Reactor Technology, Fresh Fuel, or Separation Technology. The user can, for example, choose to see only fuel cycle options that do not have recycling, or only fuel cycle options that employ molten salt reactors, or all two-stage fuel cycle options that also use metal driver fuel for a sodium-cooled fast reactor.

Another example of the enhanced search facility is shown in Figure 3. This figure also shows the parameter selection box on the left hand side of the page. The user can filter the fuel cycle options that are displayed based on: the fuel cycle strategy, the number of stages, the spectrum(a) of the reactor(s) used in the fuel cycle option, the reactivity(ies) of the reactor(s) used in the fuel cycle option, the type of incoming fuel in equilibrium (uranium, thorium, or a combination of uranium and thorium), what is recycled (nothing, plutonium, transuranics, or uranium-233 with or without transuranics), and whether enrichment is needed. The user can, for example, choose to see only nuclear fuel cycle options that are single stage, or only options that have thorium as fresh fuel at equilibrium, or all two-stage options for which enrichment is not needed. The characteristics used to categorize the nuclear fuel cycle options in this figure are the same characteristics used to group fuel cycle options for the Fuel Cycle Evaluation and Screening (Wigeland 2014).

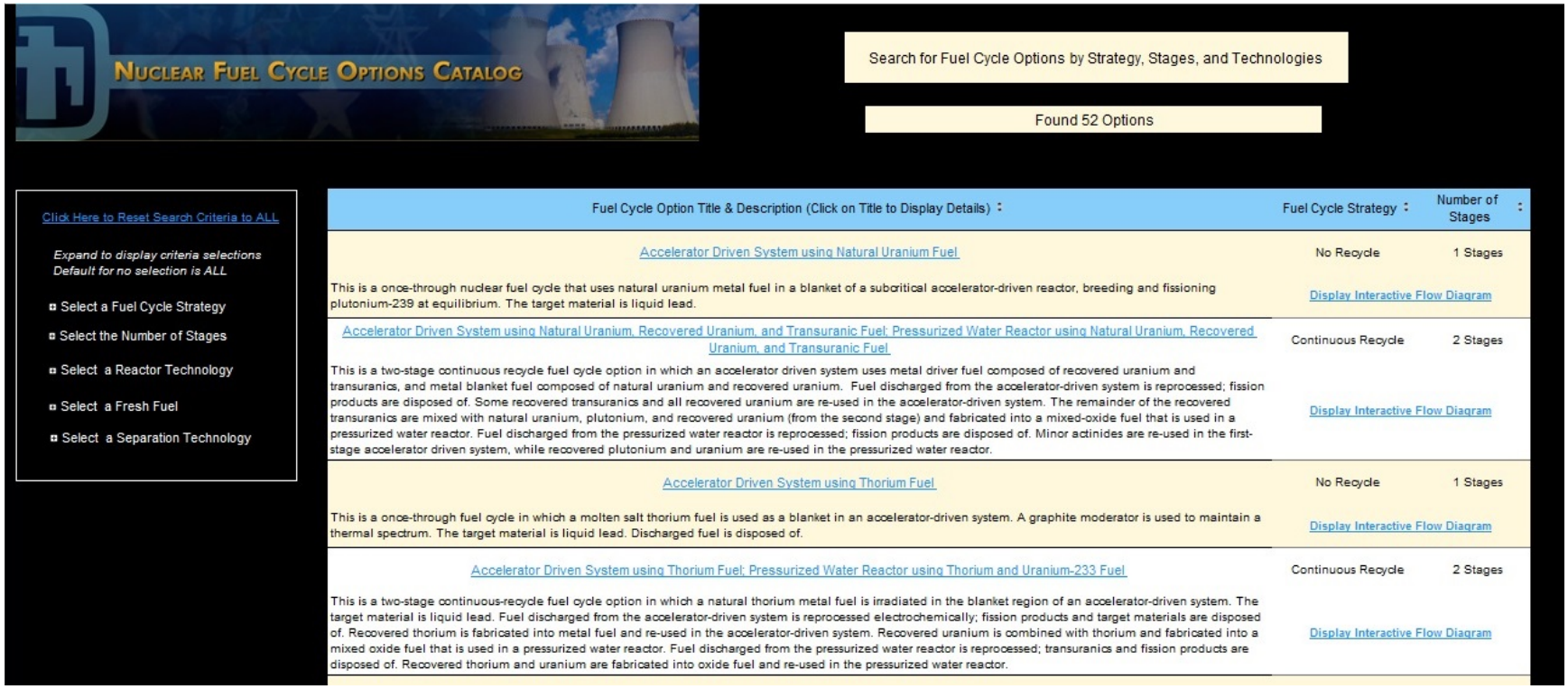

Figure 2. Search facility that filters nuclear fuel cycle options by technology used in the option

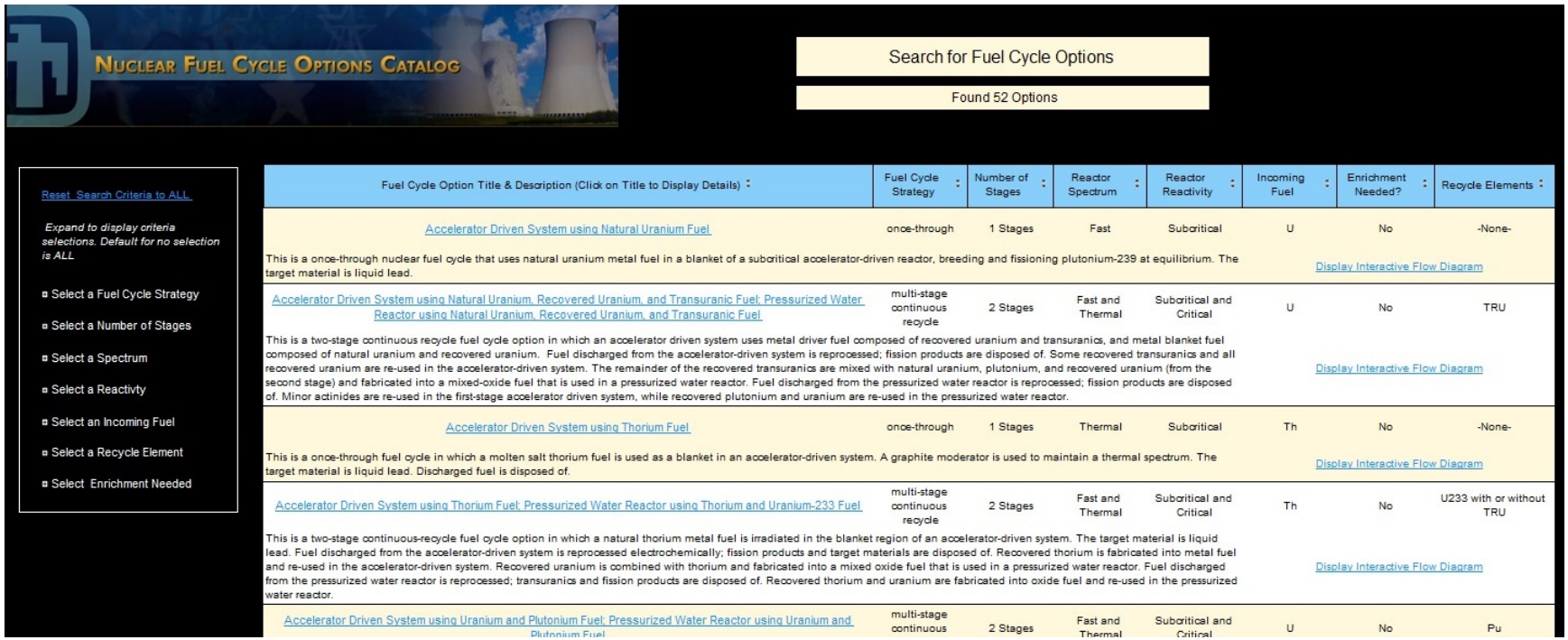

Figure 3. Search facility that filters nuclear fuel cycle options by their physics characteristics

2.2 Fuel Cycle Evaluation and Screening Webpage

In late 2011, the DOE Office of Nuclear Energy chartered a study on the evaluation and screening of nuclear fuel cycle options, referred to as the Evaluation and Screening Study (Wigeland 2014). One of the additions to the nuclear fuel cycle options catalog was a summary of the Evaluation and Screening Study, links to the main body of the report and most of the appendices, and a database report that gave the results of the study. This information is found under the Fuel Cycle Evaluation and Screening tab on the Nuclear Fuel Cycle Options Catalog home page, as shown in Figure 4.

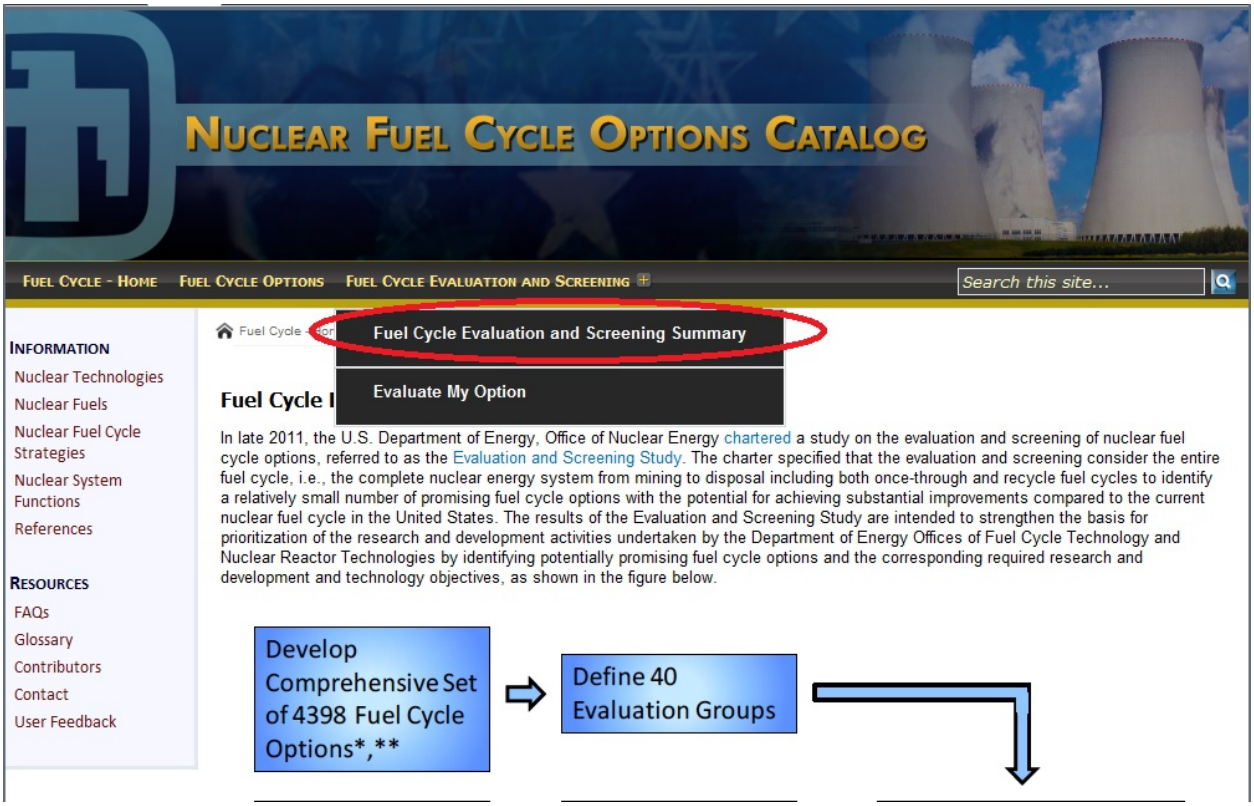

Figure 4. Location of summary of Fuel Cycle Evaluation and Screening on catalog website

Scrolling down to the bottom of the webpage takes the user to a link to a database report that shows the results of the Evaluation and Screening Study for all 40 fuel cycle evaluation groups. This report allows the user to filter the evaluation groups shown by evaluation and screening result and by evaluation group number. For each evaluation group shown in the database report, the report gives the evaluation group name, a link to the fuel cycle option that served as the analysis example for the evaluation group, a description of the evaluation group, and the results of the evaluation and screening for each of the evaluation criteria and metrics used in the study.

2.3 "Evaluate My Option" Webpage

One of the additions to the nuclear fuel cycle options catalog was the capability for a user, who had developed a nuclear fuel cycle option or had an idea for one, to be able to determine how the envisioned option would perform against the criteria and metrics used in the Evaluation and Screening Study (Wigeland 2014). The capability to "Evaluate My Option" is found under the Fuel Cycle Evaluation and Screening tab on the Nuclear Fuel Cycle Options Catalog home page, as shown in Figure 5.

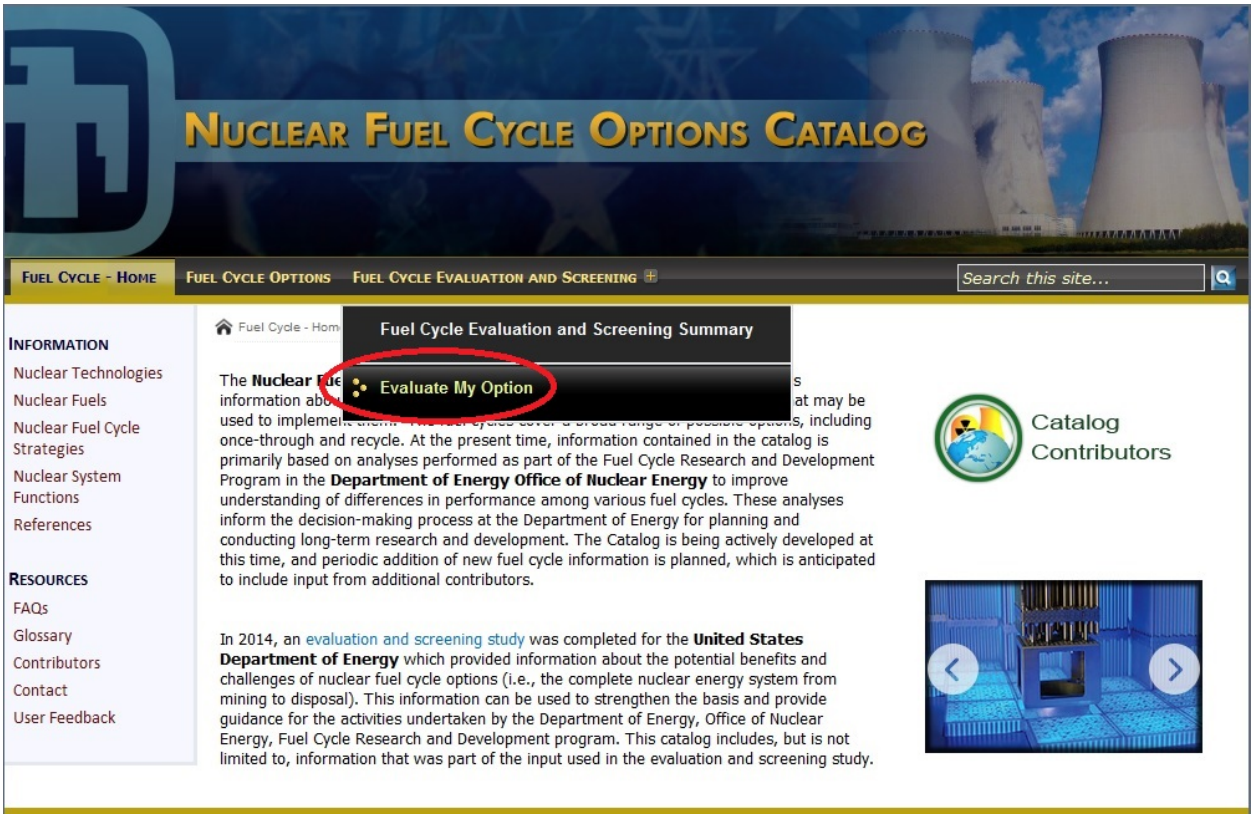

Figure 5. Location of "Evaluate My Option" on catalog website

When the user clicks on “Evaluate My Option,” a new page opens up, as shown in Figure 6. This webpage is the starting point for a series of questions that are posed to the user regarding the fuel cycle option’s recycle strategy, reactivity(ies), spectrum(a), fresh fuel, recycled elements (if any) and whether or not enrichment is needed. These questions are asked in a particular order and have predetermined answers (per the defined Evaluation Groups in Wigeland (2014, Appendix B)). The user can go to the previous screen at any time by clicking on “Previous” or can start over at any time by clicking on “Start Over.” The answers to some questions determine possible answers to subsequent questions. For example, if a user selects thorium as the fresh fuel, then the only recycled element shown to the user for selection is ^{233}U. If the user selects uranium as the fresh fuel, then the user can choose either plutonium or transuranic elements as the recycled elements. If the user selects uranium and thorium as the fresh fuel, then the user can choose plutonium, transuranic elements, or ^{233}U as the recycled elements.

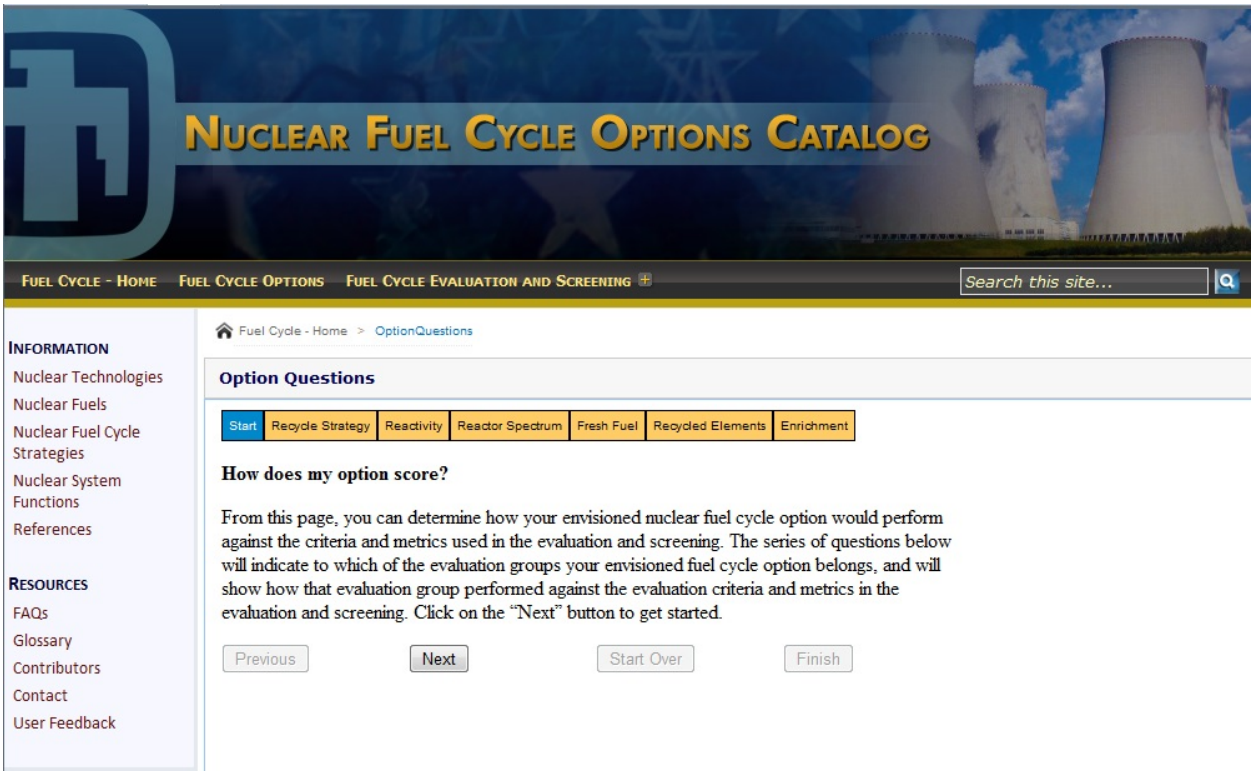

Figure 6. Starting webpage for series of questions for the "Evaluate My Option" capability

2.4 On-Line Fuel Cycle Data Package Entry Process

The current process for putting information regarding fuel cycle options, reactors, and fuels requires the person or group developing the information to complete a Fuel Cycle Data Package (FCDP). The FCDP can be either a System Datasheet or a Technology Datafile (Kim et al. 2013). A System Datasheet contains the information on the specific fuel cycle option, such as summary description of fuel cycle option, material flow diagram, mass flow data, references, etc. A Technology Datafile contains wiki-style generic information on a nuclear fuel cycle technology used in the fuel cycle option. The fuel cycle technologies include fuel type, nuclear power plant/transmutation system, and reprocessing/separations technologies.

The FCDP is completed by the originators, and then is sent to an internal reviewer and an external reviewer. Once comments from the reviewers have been addressed, it is sent for final approval. Once the FCDP has been approved, the information in the FCDP is typed into the Fuel Cycle Options Catalog manually. To ensure that no mistakes were made in transcribing the information from the FCDP to the catalog, the information in the catalog is then verified by a knowledgeable person who is independent of both the development of the information and the inputting of the data into the catalog. Any mistakes are corrected, and the information is then made available on the public catalog website.

To streamline this process, personnel have been working on creating the capability for fuel cycle option and technology developers to enter the data directly into the catalog, have it reviewed as required, and have it approved before making it available on the public catalog website. This would mean that the data would no longer have to be entered into the catalog by a third party and, thus, that this data entry would

not need to be verified by another independent reviewer. The verification process would be part of the initial review process, not an additional step.

This capability, called the Option Manager, has been developed during FY15, although it is not complete. A sample webpage for entering the parameters for a sodium-cooled fast reactor for a demonstration option is shown in Figure 7. Remaining tasks to be done include developing a review and approval procedure, developing instructions for users, and developing a procedure for capturing the references used to support the information in the FCDP.

2.5 Information Added to the Catalog

Over the course of FY15, several new options were added to the catalog and their verification was completed. These options are not analysis examples and were not needed for the Evaluation and Screening. The seven options that were added are:

- Pressurized water reactor using enriched uranium fuel with a seed/blanket fuel arrangement
- Pressurized water reactor using low-enriched uranium fuel in the first stage; pressurized water reactor using mixed oxide fuel in the second stage
- Fusion-fission hybrid using depleted uranium and /or natural uranium fuel
- Pressurized water reactor using low-enriched uranium fuel in the first stage; high temperature gas reactor using tristructural-isotopic transuranic (TRISO-TRU) fuel in the second stage
- Pressurized water reactor using low-enriched uranium fuel in the first stage; heavy-water reactor using mixed-oxide fuel in the second stage. This is known as “direct use of pressurized water reactor spent fuel in Canadian deuterium uranium reactor,” or DUPIC.
- Pressurized water reactor using low-enriched uranium fuel in the first stage; pressurized water reactor using plutonium and recovered uranium fuel in the second stage
- Pressurized water reactor using thorium and uranium mixed-oxide fuel in the first stage; high temperature gas reactor using recovered thorium and recovered uranium carbide fuel in the second stage

In addition, the Fuel Cycle Options Campaign provided six additional fuel cycle options, two additional reactors, and one additional fuel for inclusion in the catalog. This additional information was provided late in the fiscal year and will be entered into the catalog during the first few months of FY16. The six additional fuel cycle options are:

- Accelerator-driven system using plutonium, natural uranium, and recovered uranium fuel
- Sodium-cooled intermediate reactor using plutonium, natural uranium, and recovered uranium fuel

Nuclear Fuel Cycle Option Catalog Option Manager

Edit Technology Parameter Values

Option	Demonstration 1		
Stage	Stage 1 - This is a description of Stage 1 of the option.		
Stage Architecture	(D) Transmutation Systems		
Stage Architecture Technology	Sodium-cooled Fast Reactor (SFR) (breeder or burner)		
Technology Parameter	**Parameter Value**	**Parameter Unit**	**Actions**
Average Accelerator Power Requirement	TBD	MWe	Edit Parameter Value
Capacity factor	TBD	%	Edit Parameter Value
Core Configuration	TBD	Text	Edit Parameter Value
Core Thermal Power	TBD	MWth	Edit Parameter Value
Electrical Energy Generation Sharing	TBD	%	Edit Parameter Value
Net Thermal Efficiency	TBD	%	Edit Parameter Value
NPPT Technology Identifier	TBD	Text	Edit Parameter Value
Specific Power Density	TBD	MW/Initial Heavy Metal Metric Ton	Edit Parameter Value
Technology Readiness Level	TBD	Scale from 1 to 9	Edit Parameter Value
Technology Readiness Level - Brief Justification	TBD	Text	Edit Parameter Value

Figure 7. Sample Option Manager webpage

- Reduced-moderation boiling water intermediate spectrum reactor using plutonium, depleted uranium, natural thorium, recovered thorium, recovered uranium-233, and recovered uranium-238 fuels
- Molten salt fast reactor using plutonium and uranium fuel
- Reduced-moderation boiling water intermediate spectrum reactor using plutonium, depleted uranium, natural thorium, recovered thorium, recovered uranium-233, recovered uranium-238, and transuranic fuels
- Sodium-cooled fast reactor using plutonium and recovered uranium; molten salt thermal reactor using plutonium and recovered uranium fuel

The two reactors are:

- Supercritical water reactor
- High-conversion water reactor

The fuel is:

- Reduced-moderation boiling water intermediate spectrum uranium oxide fuel

2.6 Ongoing Maintenance Activities

In FY15, the catalog staff also performed ongoing maintenance activities, such as making sure the website and database continued to work when SNL's network managers updated software or equipment, and updating the catalog requirements document (Price et al. 2015).

3. REFERENCES

Kim, T. K., E. A. Hoffman, and T. A. Taiwo, 2013, *Completion of Fuel Cycle Data Package System Datasheets for 2013 Evaluation and Screening*. ANL-FCT-333, FCRD-FCO-2013-000165, Fuel Cycle Research and Development, U.S. Department of Energy, Office of Nuclear Energy, Washington, DC.

Price, L. L., A. C. Barela, R. R. Schetnan, and W. M. Walkow, 2015, *Nuclear Fuel Cycle Option Catalog Software Requirements*, FCRD-SYSE-2011-000042, Fuel Cycle Research and Development, U.S. Department of Energy, Office of Nuclear Energy, Washington, DC.

Wigeland, R., T. Taiwo, H. Ludewig, M. Todosow, W. Halsey, J. Gehin, R. Jubin, J. Buelt, S. Stockinger, K, Jenni, and B. Oakley, February 2014. *Nuclear Fuel Cycle Evaluation and Screening – Final Report*, FCRD-FCO-2014-000106, Fuel Cycle Research and Development, U. S. Department of Energy, Office of Nuclear Energy, Washington, DC.